The Brain As A Black-Box?: ER-fMRI Latency Estimation Of Interleaved Responses To Short Visual, Auditory, And Motor Stimuli

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Purpose

This study investigated the degree to which one can infer ordering of neuronal events in spatially and functionally separate brain regions, given the information encoded in the hemodynamic response to a short stimulus.

Introduction

Event-Related fMRI relies on the estimation of the hemodynamic response to short stimuli. The precise relationship of this response to neuronal firing is an area of active investigation. There is evidence of the encoding of the temporal ordering of neuronal firing within this response for spatially contiguous brain regions [3], but less so for disparate regions [4] due to potential confounds such as different vascular supplies, and different functional responses. The degree to which information is preserved is still largely unknown. We have designed a battery of stimuli probing visual, motor, and auditory regions of the brain in specific orders. If temporal ordering is preserved, this should be reflected in the latency of the hemodynamic response.

Methods

We applied a latency estimation technique utilizing sequential weighted linear regression [1]. This provided us with an estimate of the amplitude and latency, a functional latency map (FLM) for every voxel in the brain surpassing criteria for goodness of fit, amplitude, and latency. Three subjects were examined. GE-EPI imaging (TR=1s, TE=40ms, st=5mm, matrix=64x64 (recon to 128x128), FOV=23mm, 18 slices) were acquired for either 5 or 10 minutes per run on a 1.5T Phillips NT scanner. Timing correction (windowed sinc interpolation) and motion correction (frequency based) [2] were performed on all volumes.

The stimuli were 1) A 0.5s 8Hz full-field reversing checkerboard every 16.4s, after which the subject was asked to press a response button. 2) the same stimuli, but with sequentially decreased ISI, down 3.2 seconds (both randomized and fixed ISI), 3) A 0.5s 8 Hz full-field reversing checkerboard every 20.4s, followed 10.2s later by a 0.5s graded tone, after which the subject was instructed to press a response button. Reaction times were recorded for all subjects and used to fit the response in the motor cortex.

Results

Visual, Auditory, and Motor areas were reliably activated in all three subjects with the paradigm described above. The latencies demonstrated evidence of the preservation of temporal ordering. The FLM from subject 3 is presented in Figure 1.

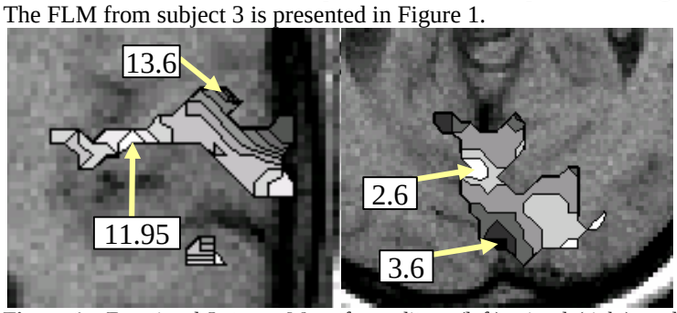
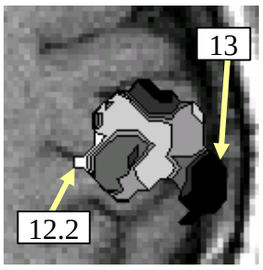


Figure 1: Functional Latency Maps for auditory (left), visual (right), and motor (top of next column) cortex. Black lines are iso-latency contours in 200ms gradations. The Colormap is a linear grayscale indicating latency with lighter being earlier, and darker being later. Latency is defined as the time (secs) when the fitted response first rises above zero.



Latencies from the earliest voxel in each brain region for the subjects are presented in Tables 1-2.

Estimated Latencies in Visual-Auditory-Motor Experiment

Subject	Visual	Auditory	Motor
1	2.8	11.6	11.8
2	2.6	11.6	12.8
3	2.6	11.95	12.2

Table 1: Estimated latencies (sec) for each subject in visual, auditory, and motor cortex for the single voxel with the *earliest* latency in each of the areas. In all three subjects the stimuli are separated, although the delay between auditory and motor is surprisingly long for subject 2. Note that the Auditory stimuli was presented 10.2s after the visual stimuli.

Discussion

There is evidence that temporal ordering of neuronal firing is preserved in the hemodynamic response to fMRI, even across functionally different regions. In information bearing, the HDR may be considered a reduced version of the electrical activity, perhaps with additional confounds. While this is an intuitively satisfying result, there are some other aspects requiring further analysis. The delay between regions is larger than would be expected if the hemodynamic response were simply a smoothed and delayed electrical response. There is a large latency spread across regions, due to the interaction between flow, oxygenation, and other factors. For this reason we focused primarily on the *earliest* latency in each regions. Additionally, we noticed the latency in the thalamic region was slightly earlier than that in the auditory cortex, which could indicate among other things, sub-threshold activation of the auditory cortex prior to thalamic feedback. However, the expected ordering of at least visual, auditory, and motor cortices was observed and our purpose was achieved.

References

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